International Conference on Soil Science

Accra, 7 – 11 January 2007

The Soil diagnostic method to compute fertilizer requirements in cocoa plantations

Snoeck D.
CIRAD, Ghana
Abekoe M.K.
Soil Science Department, University of Ghana, Legon
Afrifa A.A., Appiah M.R. and Ofori-Frimpong K.
Cocoa Research Institute of Ghana, Tafo-Akim

Abstract

Soil analysis is not often used for fertilizer recommendations, because it is difficult to interpret. We developed a soil diagnostic software programme to help the agronomist to understand and interpret soil analysis to formulate fertilizer requirements (formulae and doses) on cocoa plantations.

The methodology used to determine the fertilizer needs is based on the Diagnostic Soil method developed by Jadin and Snoeck (1985). The model evaluates the levels of nutrients in the soil and the ratios among them at the soil's pH to determine the required amount of Nitrogen and Phosphorus. Once this is done, the K, Ca and Mg ratios are compared to determine the amounts of each nutrient. The final recommendations are computed to reach the optimum values and to compensate for the nutrients exported by the yields.

The software was tested on some peasant cocoa farms used in a Cocoa Research Institute of Ghana (CRIG) fertilizer trial to compare and classify them according to their nutrient needs (Appiah *et al*., 2000).

The results show that most of the farms need P fertilizers. Among the exchangeable bases, Ca was more often found as being the limiting factors.

The results indicate that the soil diagnostic method can be a powerful tool for fertilizer recommendation to be made on cocoa farms.

Introduction

Optimum productivity of any cropping system depends on adequate supply of plant nutrients. Although one or more nutrients are commonly applied to most crops, the quantity of nutrients removed in the harvested crop is generally much greater than the quantity added. Continued removal of nutrients with little or no replacement will increase the potential for future nutrients related plant stress and yield loss.

When the soil does not supply sufficient nutrients for normal plant development and optimum productivity, application of supplemental nutrients is required. The proper rate of plant nutrients is determined by soil testing.

Soil analyses are routinely carried out in cocoa plantations in Ghana, but are not often used for fertilizer recommendations, because they are difficult to interpret. A soil diagnostic model was developed to help the agronomist to easier understand and interpret soil chemical data (level of nutrients, N/P and K-Ca-Mg ratios) in order to formulate adequate fertilizer recommendation for cocoa plantation.

The Soil diagnostic model was established from the results of many trials in Côte d'Ivoire and Togo. To make the use of the model easier, we developed a software programme under a commonly used spreadsheet. It gives the amount of fertilizers needed to correct the soil nutrient deficiencies and to maintain or increase the yields.

The agronomist using the model must have sufficient knowledge in soil fertilization practices. In particular, he must a) understand and interpret soil analytical data; b) know the critical levels of soil nutrients and c) choose the type of fertilizers appropriate to the soil conditions and available on the local market.

The objective of this paper is to demonstrate how the model works and compare recommendations generated from the model with the results obtained from CRIG fertilizer trials. Once this is done, we will be able to use it to establish fertilizer requirements on coca farms in Ghana.

Materials and methods

The methodology used to determine the fertilizer rate is based on the Cocoa Soil Diagnostic model developed by Jadin and Snoeck (1985). With the experience drawn from the numerous fertilizer trials, the authors of the model defined the threshold levels of nutrients and ratios between N and P, total exchangeable bases (TEB) and N and K, Ca and Mg ratios. The model then compares the actual levels of nutrients in the soil with these optima to compute the required amounts of the major nutrients in order to correct the soil nutrient deficiencies and to compensate for the quantity of nutrients exported through cocoa pods during harvest.

The recommendations given by the model are compared with the results obtained from the CRIG's fertilizer trial done in some peasant cocoa farms. The fertilizer trial used is described by Appiah *et al*. (2000).

Presentation of the software

The first step is to enter the data obtained from the soil chemical analyses. This gives a complete database of all the soils analysed (Fig. 1). As the software is based on a commonly used spreadsheet, it makes it easy to share information with other researchers.

Table 1: Sample database of soil samples

Add a new soil analysis | Diagnostic of this soil | English | Français

Country	Title	Cat	C+S	C	N	P total	P ava	K	Ca	Mg	Al	CEC	pH	P method
Cameroun	Santa, taille - interligne		45,00	6,66	0,383		1,4	0,65	1,64	0,62	0,85	17,21	5,80	Truog-Br2
Cameroun	Santa, taille - jupe		45,00	6,71	0,384		2,1	0,24	0,35	0,10	2,06	15,00	5,30	Truog-Br2
Côte d'Ivoire	Soubré		45,00	6,00	0,076	3230	32,0	0,13	2,38	0,37		3,61	5,80	Olsen-Dal
Côte d'Ivoire	Zagné		45,00		0,092	3330	33,0	0,07	2,10	0,76		4,42	5,80	Olsen-Dal
Ghana	Abenia Broken forest	w	35	2,71	0,189	250		0,24	0,94	0,66		5,80	4,28	Truog-Br2
Ghana	Adawso	e	22	1,51	0,150	144		0,60	8,67	1,92		8,605	7,175	Truog-Br2
Ghana	Adiembra	c	30	2,11	0,321	269		0,40	13,52	2,61		14,03	8,00	Truog-Br2
Ghana	Adomfe, clonal garden	c	30	2,00	0,250	550	15,0	0,24	3,20	1,12		5,95	4,30	Olsen-Dal
Ghana	Adzintam	e	30	1,76	0,195	200		0,25	8,365	3,475		12,65	6,725	Truog-Br2
Ghana	Akroso	c	25	1,08	0,211	102		0,13	1,43	0,71		4,42	6,10	Truog-Br2
Ghana	Akumadan	c	37	2,18	0,180	150		0,18	1,95	0,80		14,60	4,80	Truog-Br2
Ghana	Ankasa Broken forest B 856	w	35	1,13	0,088	120		0,09	0,32	0,25		5,60	4,40	Truog-Br2
Ghana	Ankasa do B 860	w	35	1,42	0,098	120		0,09	0,54	0,41		5,60	4,40	Truog-Br2
Ghana	Ankasa do B 860	w	35	1,32	0,086	120		0,23	0,48	0,35		5,60	4,35	Truog-Br2
Ghana	Ansum-Dissue Intergrade	w	50	1,93	0,164	150		0,27	5,34	1,80		12,04	5,35	Truog-Br2
Ghana	Ansum-Disue Intergrade do	w	50	1,59	0,164	150		0,12	0,97	0,58		7,38	5,05	Truog-Br2

By clicking on the command button "Diagnostic of this Soil", the software computes the threshold levels of each of the nutrients and the ratios between them. The results are displayed in a second window which also shows a first interpretation of the soil analysis (Fig. 2):

- Comments on ratios between the soil nutrients before correction and
- Appreciation of recommendations and expected new soil levels of nutrients after increasing the saturation to 60% (minimum by default).

Table 2: Sample of soil analysis: actual data and expected after an increase of Base Saturation to 60%

Country	Ghana				11/11/2005
Title	Abenia Broken forest B 859				
Clay + fine silt (%)	35		Expected values after fertilization		
Carbon (%)	2,83	C/N = 16,5			
Nitrogen (%)	0,172				
P total (ppm)	250	N/P = 6,9			
P available (ppm)			100,0		Truog-Br2
K (meq%)	0,165	8,1%	0,312	8,0%	0,15
Ca (meq%)	1,135	55,6%	2,652	68,0%	1,52
Mg (meq%)	0,740	36,3%	0,936	24,0%	0,20
Al^{3+} (meq%)					
C.E.C. (meq%)	6,500				
pH (H_2O)	4,50				
Sum of Exch. Bases	2,04		3,90		
Base Saturation	31,38		60,00		
∑ (exch. Bases) / N	4,76		5,84		

Print analysis

Calculate expected values

Back to formulae

Comments

Test (exch. B.) / N ==> increase bases After modif. ==> increase bases

N/P (normal = 1,5 -- 2) P is low => increase P

The agronomist will then click on the "calculate expected values" button. He will be asked to enter the optimal dose of phosphorus. His choice will influence the quantity of phosphate-enriched fertilizers to be recommended.

Then, he will be asked to enter the %K, %Ca and %Mg ratios in order to reach the optimal balance of 8%, 68% and 24%. To be able to propose a reasonable fertilizer recommendation, a base saturation of between 60 to 100% is required.

Some of the parameters required for the model to work are: soil depth, apparent density, expected yield, age of trees and number of trees per hectare and the type of each fertilizer and percentage of P, Ca, K, and Mg oxides are also required.

A sample output form of the results given by the model is shown in Table 3.

Table 3: Sample output results of fertilizer choice and recommendations

Choice of fertilizers : Formulae and doses

The doses are computed per cocoa tree.

				Amount of fertilizer for:	
				Soil correction *(total doses)*	Yield exportation *(annual doses)*
P fertilizer :	% P_2O_5	35	=> needs :	3.402 g	74 g
	% CaO	50			
	% effic.	*50*			
K fertilizer :	% K_2O	60	=> needs :	500 g	11 g
	% effic.	*100*			
Ca and Mg fertilizers	% CaO	55	=> needs :	469 g	2 g
	% MgO	40			
	% effic.	*100*			
Mg only fertilizer	% MgO	100	=> needs :	0 g	1 g
Complete fertilizer	% N	100	=> needs :	0 g	
	% P_2O_5	0			
	% K_2O	0			

In this sample output, the total amount of P fertilizer needed to correct the P level in the soil will be applied over 5 years. The K and Ca correction can be done over 1 year only.

The fertilizers needed to compensate for yield exportation is expressed as annual doses.

Test of the Diagnostic Soil method in a fertilizer trial

We compared the fertilizer recommendations generated from the Soil Diagnostic method with the results obtained from a traditional fertilizer trial done in some peasant cocoa farms. The trial compared twenty cocoa farms receiving 129 kg P_2O_5 as TSP and 76.5 kg K_2O as Muriate of Potash fertilizers during 3 years to control plots that did not receive any fertilizer. Soil analyses were done at the beginning and after the 3 years in fertilized and control plots. Yields were also recorded. The results of the trial are described by Appiah *et al*. (2000).

The software compares the properties of the soils with the optimal ratios. Scatter diagrams were drawn and the optimal values were represented by regression lines.

Results and Discussion

The changes observed in soil nutrients in the various farms of the trial are presented in Figure 1 for P and Ca levels due to TSP fertilizer addition, and in Figure 2 for K levels due to KCl (Muriate of Potash) fertilizer application.

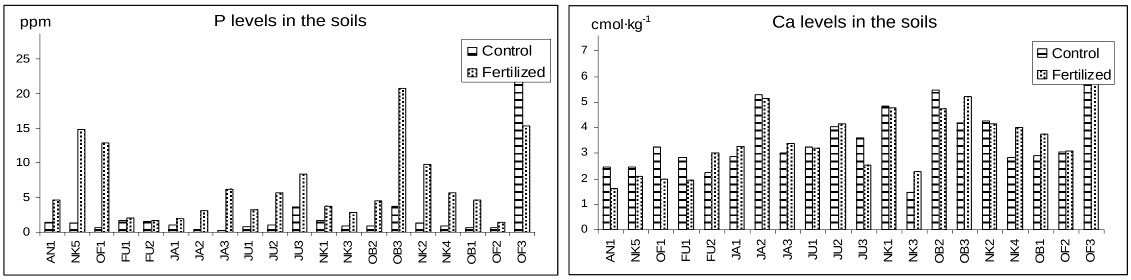


Fig 1: Phosphorus and Calcium levels in soils due to TSP addition

The application of TSP fertilizers produced an increase of P levels in all soils. The Triple Super Phosphate (TSP) fertilizer also contains Calcium (from $Ca_{10}(PO_4)_6$) and its application is expected to increase the Ca content of the soil. However, there was no significant increase in Ca content in the soils due to the application of TSP.

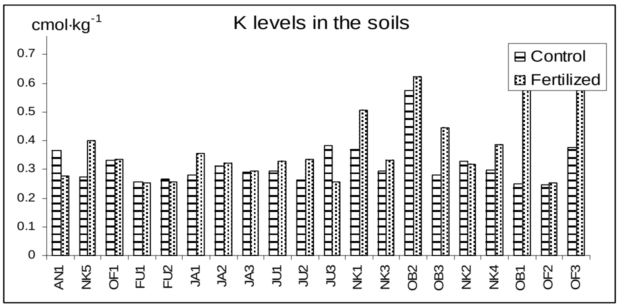
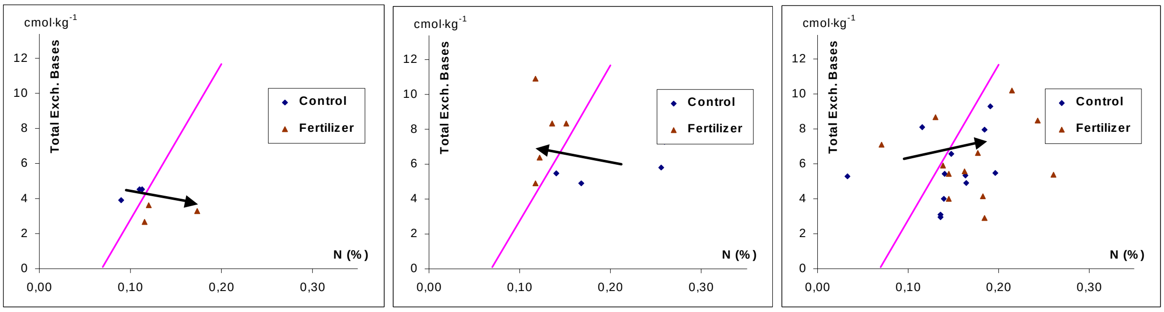


Fig. 2: Potassium levels in soils due to KCl addition

Increase in K levels within the 3 year period was very low, except for 3 farms (OB1, OF3 and NK1). K levels were already adequate before the application of KCl since all farms have K levels greater than 0.2 $cmol.kg^{-1}$ soil.

Figures 3 and 4 show the ratio of Total Exchangeable Bases and Nitrogen (TEB/N) and also the exchangeable bases ratios for the control and fertilized plots. It also shows their contents due to fertilizer additions.



3.1. AN1, NK5, OF1 3.2. NK2, NK4, OB1, OF2, OF3 3.3. Other plots

Fig 3: Classification of soils in the fertilizer trial by their TEB / N ratios

At the beginning of the trial, before application of fertilizer, most of the farms needed a correction of exchangeable bases, except three.

On those three farms (AN1, NK5, OF1), despite the input of P and Ca through TSP fertilizers, the levels of Ca were reduced causing a reduction of TEB (Figure 3.1).

After three years of fertilizer applications, most of the farms had an increase in Nitrogen, except for 5 of them. Those 5 farms now need a Nitrogen fertilizer, which was not the case at the beginning of the experiment. Their N levels were reduced, with K and Mg levels increasing slightly (Figure 3.2).

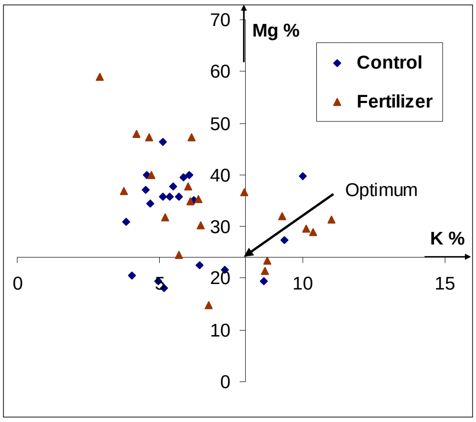


Fig. 4.1

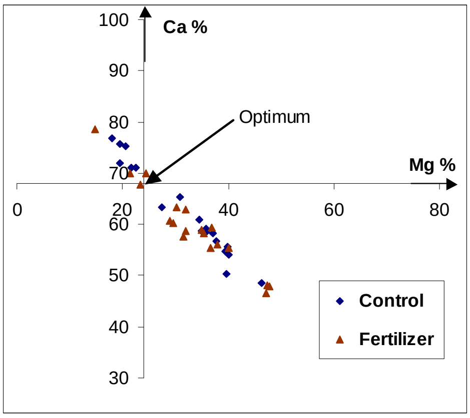


Fig. 4.2

Fig. 4: Classification of soils by their K, Ca and Ca, Mg ratios (in % of TEB)

The optimum %K is 8% according to the model. All farms represented by dots below the optimum K level will require application of K fertilizer.

The optimum %Ca is 68%, and the Figure shows that most farms will need Ca fertilizer application. It confirms that the Ca brought by the TSP fertilizer was not sufficient to reach the optimum levels. Most soils will therefore require more Ca addition, using separate Calcium fertilizer. Figure 4.2 shows that soils with high content of Ca have low Mg and vice-versa.

The Soil Diagnostic software was used to define optimum doses for each of the nutrients. We input 100% oxide in the formulae, to enable comparison of identical nutrient compounds.

The fertilizer requirements in K, Ca and Mg nutrients recommended by the model are presented in Figure 5.

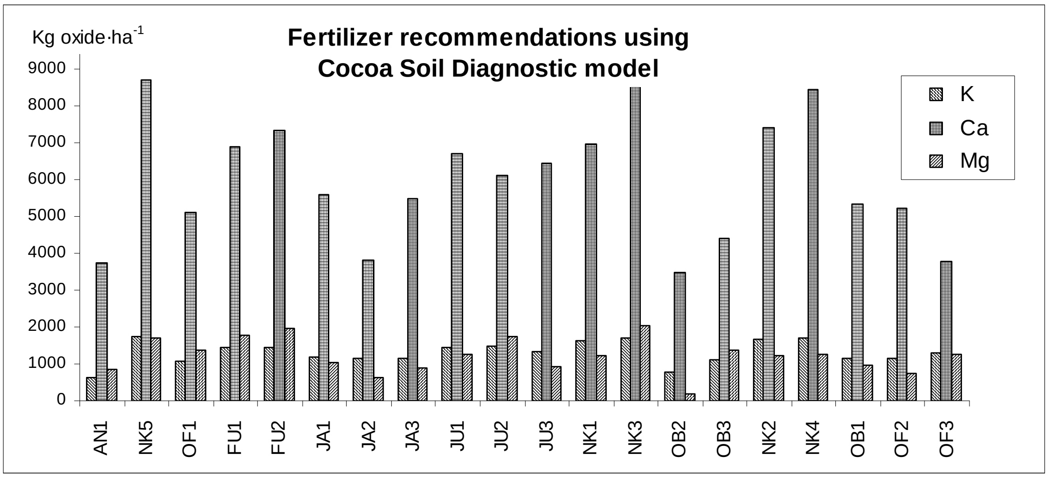


Fig. 5: Fertilizer requirements for each site as defined by the Soil Diagnostic model

The model suggests that very high amounts of Calcium fertilizers are needed with average amounts of K-based and Mg-based fertilizers. This recommendation confirms the results obtained from Figures 1 and 4.

Conclusion

In the CRIG fertilizer trial, the Soil Diagnostic software recommends more K and Ca than what was used by Appiah *et al.* (2000). The fact that only little accumulations of both K and Ca nutrients in the soil were observed supports favourably the recommendations from the model and would give better results than traditional blanket P and K fertilizers.

The results indicate that the soil diagnostic method can be a powerful tool to better understand nutrient requirements and for fertilizer recommendation to be made on cocoa farms. The use of the model would enhance the work of the agronomist to achieve maximum fertilizer use efficiency on peasant cocoa farms in Ghana. The results also confirm that the method can be used for Ghana soils.

The soil diagnosis method demonstrates that a single formula and dose of fertilizer for all the farms is not advisable. For a period of more than three years, the formulae used in the trial might produce a decrease in yield.

References

Appiah M.R., Ofori-Frimpong K., Afrifa A.A. (2000) Evaluation of fertilizer application on some peasant cocoa farms in Ghana. Ghana Jnl. Agric. Sci. 33,p. 183-190.

Jadin P., Snoeck J. (1985) La méthode du Diagnostic sol pour évaluer les besoins en engrais des cacaoyers. CCT, vol. 29 (4), p. 255-261.